SPECIFICATION

A BALANCE TRAINING DEVICE

5   FIELD OF THE INVENTION

The present invention relates to a balance training device for training the sense of equilibrium of a user by swinging a plate with a user carried thereon.

10   DESCRIPTION OF THE PRIOR ART

There is a known device according to a prior art as an actively operating balance training device, including one directed to an application in a sitting posture (see, for example, Japanese Patent Publication No. 2000-102523)

15   and another having a complicated linkage mechanism (see, for example, Japanese Patent Publication No. 2001-286578).

Such an actively operating balance training device of the prior art has a drawback that it can provide only the training in the sitting posture for a user but it is

20   difficult to provide the training in the leg segment, which is essential to control the sensible balance. There is another problem in association with such a device of the prior art that a mechanism for controlling a swing motion is complicated, as it has employed a plurality of linkages,

25   for example, thus being subject to a higher risk of failure of the device. The device of the prior art has been also associated with another drawback that it is unable to provide the training independently and exclusively directed

to each of three organs, including a semicircular canal, a vision and a deep sensibility, each governing a personal sense of equilibrium.

An object of the present invention is, on the premise
5   of its use in a standing posture for realizing the training in the leg segment, to provide a balance training device that allows a motion of a plate with a user carried thereon to be achieved in the form of a rotation in the lateral direction with respect to the body of the user while
10   eliminating a need for any complicated linkage mechanism. Another object of the present invention is to realize the specified training that may be provided independently and exclusively directed to each of the three organs, including the semicircular canal, the vision and the deep sensibility,
15   each governing the personal sense of equilibrium.

The term "deep sensibility" used herein refers to the sensibility to recognize a position for a certain part to be taken relative to other parts of a body of a person experiencing the training and the deep sensibility is
20   classified to a proprioceptive sensibility. The deep sensibility is provided by the receptors, including a contact pressure receptor of skin, a muscle spindle, a pacinian corpuscle of subcutaneous tissue and a neural free terminal (cited from: "Medical Dictionary, 2nd Edition",
25   Ishiyaku Publishers Inc., 1996).

SUMMERY OF THE INVENTION

According to an aspect of the present invention,

provided is a balance training device usable in a standing posture or a sitting posture, said device comprising: a plate 1 for carrying a user; a motor 2 for driving said plate 1; a sensor 3 for measuring a rotation angle of said

5   plate; a torque measuring mechanism for measuring a torque applied to said plate; a kinetic model analyzer 5 for determining a target rotation angle for said plate from said measured torque; and a motor controller 6 for controlling said motor in accordance with a predetermined

10   kinetic model.

The balance training device of the present invention may be characterized in that said plate 1 is rotated around an axis of rotation extending in parallel with a top surface of the plate.

15   The balance training device of the present invention may have a configuration in which said top surface of said plate 1 coincides with a plane containing a center of the axis of rotation.

The balance training device of the present invention

20   may have a configuration in which said top surface of said plate 1 is spaced apart by a certain distance from the center of the axis of rotation.

The balance training device of the present invention may have a configuration in which said torque measuring

25   mechanism has a pair of force plates 41 each comprising an integrated sensor unit composed of one sensor for measuring a load applied to said plate 1 and the other sensor for measuring a position of a center of loading.

The balance training device of the present invention may have a configuration in which said torque measuring mechanism comprises a sensor 42 for measuring a torque applied to said plate 1, which is mounted on a shaft of the

5   motor 2 for driving said plate 1.

The balance training device of the present invention, in one configuration, may have a kinetic model analyzer 5 characterized in that a motion of said plate 1 is defined by a spring constant, a viscous braking coefficient and a

10   moment of inertia, all of which are virtual.

The balance training device of the present invention, in one configuration, may have a motor controller 6 for controlling the plate 1 with a user carried thereon in accordance with an angle of equilibrium that has been

15   arithmetically determined by said kinetic model analyzer 5. The term "angle of equilibrium" used herein refers to an angle making the force applied by the user in balance with the rotational force of the motor. Increasing or decreasing of the rotational force will modify the angle of

20   making the equilibrium.

Said balance training device of the present invention can provide the training independently and exclusively directed to each one of three organs, including the semicircular canal, the vision and the deep sensibility,

25   each governing a personal capability of balancing.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic perspective view illustrating

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an embodiment of a balance training device according to the present invention;

Fig. 2 is a perspective view illustrating an embodiment of a balance training device according to the present invention, showing an example including a rotation torque sensor mounted thereon;

Fig. 3 is a block diagram for controlling a measuring operation and a motor in an embodiment of a balance training device according to the present invention;

Fig. 4 is a schematic perspective view for facilitating the understanding of equations (1) and (2) for arithmetically determining a rotation torque and a kinetic analytical model for an embodiment of a balance training device according to the present invention; and

Fig. 5 provides a graphical representation of simulation results for different viscous braking coefficients with respect to an embodiment of a balance training device according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of a balance training device according to the present invention will now be described on the basis of some examples with reference to the attached drawings. Fig. 1 is a perspective view illustrating a first embodiment of the balance training device according to the present invention. This balance training device allows for training independently directed to each one of three organs, including a semicircular canal, a vision and

a deep sensibility, each governing a personal capability of balancing, in which a user carried on a plate of the device is subject to the swing motion of the plate, and also is allowed to take an active motion in a standing posture or a

5 sitting posture to thereby train his/her capability of balancing.

The balance training device comprises a plate 1 for carrying a user 4 thereon, a motor 2 for driving the plate 1, a rotation angle sensor 3 for measuring a rotation angle

10 of the plate 1, a torque measuring mechanism for measuring a torque applied to the plate 1, a kinetic model analyzer 5 for determining a target rotation angle from the measured torque, and a motor controller 6 for controlling the motor in accordance with a predetermined kinetic model. The

15 torque measuring mechanism may employ a pair of force plates 41 each serving for measuring a force applied onto the plate 1 by a left or a right foot, respectively, and then calculate the torque based on the measurements, or may employ a commercially available torque sensor 42 mounted on

20 a revolving shaft of the motor 2, which will be described later.

A clamp 7 is attached to the plate 1 in a central location of a rear edge thereof along its width direction so as to clamp the plate 1. The revolving shaft of the

25 motor 2 is fixedly attached to a back surface of the clamp 7 appropriately with a fastening means so that the center of the revolving shaft of the motor 2 may be positioned at the center of the plate 1 along its width direction and in

parallel with a top surface of the plate 1.

In this arrangement, the revolving shaft of the motor 2 may be fixedly attached to the back surface of the clamp 7 such that a center of axis of rotation of the revolving
5   shaft is positioned on a plane of the top surface of the plate 1, or in an alternative configuration, such that the center of axis of rotation of the revolving shaft is spaced apart from the plane of the top surface of the plate 1 by a certain distance. This arrangement allows for the plate 1
10   to make a swing motion around its revolving shaft when the user carried thereon take a motion and also to provide a tilting motion in an active manner by means of the motor 2. The motor 2 is adapted to be actuated and controlled externally.

15   The torque measuring mechanism may be one configuration employing the pair of force plates 41 as shown in Fig. 1 or may be the other configuration employing the commercially available rotation torque sensor 42 as shown in Fig. 2, as already discussed above.

20   In Fig. 1, the torque measuring mechanism using the pair of force plates 41 comprises the pair of force plates 41 and an arithmetic processing unit (not shown). The plate 1 includes the pair of force plates 41 each positioned on its top surface in the left and the right
25   sides axi-symmetrically with respect to the revolving shaft. Each of the force plates 41 comprises an integrated set of two sensors, including one for measuring a load applied to the plate 1 and the other for measuring a position of the

center of loading when the user takes any motions as carried on the plate 1.

The arithmetic processing unit may calculate the torque by multiplying a measurement of the pair of force plates 41 (load applied to the center of the loading) by a certain distance defined by an offset of the center of the loading from the center of axis of rotation of the revolving shaft (force X distance).

In Fig. 2, the configuration employing the commercially available rotation torque sensor allows for the rotating force (torque) applied to the plate from the motion of the user to be measured by means of a commercially available rotation torque sensor that has been attached to the revolving shaft of the motor 2.

The rotation angle sensor 3 as shown in Fig. 1 is mounted to the clamp 7, which has clamped the plate 1 at its front edge thereby to be attached thereto, and adapted to measure a rotation angle as the plate 1 is tilted.

Fig. 3 shows a block diagram illustrating a general configuration for controlling the motor by the torque measuring mechanism, the rotation angle sensor, the kinetic model analyzer and the motor controller. In Fig. 3, respective components are connected to each other in such a manner that an output from each of the torque measuring mechanism and the rotation angle sensor 3 is input to the kinetic model analyzer 5, an output from the kinetic model analyzer 5 is in turn input to the motor controller 6, and an output from the motor controller 6 is then input to the

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motor 2.

　　　　With the configuration shown in Fig. 3, the kinetic
model analyzer 5 determines a rotation angle of the plate 1
which may vary in dependence on the force applied to the

5　　plate 1 defined by the equation (1) as shown below, which
is associate with Fig. 4 for easy understanding, thus
providing the control of the motor 2.

$$J\ddot{\theta} + D\dot{\theta} + k\theta = T_m + T_d \quad \cdots \cdots \cdots \cdots (1)$$

　　　　where θ: Rotation angle of the plate (rad);

10　　　　　　　　J: Moment of inertia $(kg \cdot m^2)$;

　　　　　　　　D: Viscous braking coefficient $(N \cdot s/m)$;

　　　　　　　　K: Spring constant (N/m);

　　　　　　　　T_m: Rotation torque $(N \cdot m)$; and

　　　　　　　　T_d: Disturbance torque $(N \cdot m)$

15　　　　An operation of a balance training device according
to the present invention that has been constructed to have
the above-described configuration will now be described.
As a user puts herself/himself on the plate 1 of the
balance training device, unstable balancing ability of the

20　　user causes the plate 1 to be tilted and thus rotation
(swing motion) to be produced. The user then realizes the
tilting due to the rotation and attempts to apply the force
to either one of his/her feet to compensate for the tilting.
This may cause the force to exert against said rotation to

25　　trigger the rotation of the plate in the opposite direction,
thus carrying out a series of operations.

　　　　During this series of operations, the motor is
controlled by using the force applied by the user and the

rotation angle of the plate 1 as variable parameters under
the condition of the rotation characteristics of the plate
1 defined by the spring constant, the viscous braking
coefficient and the moment of inertia, which are all
5   virtual as shown in Fig. 4, and thereby the device can
provide the training accordingly in dependence on the high
or low level of performance in the capability of balancing
of the user. Further, a certain magnitude of rotation may
be applied to the plate 1 as the disturbance. That is, the
10   device also allows for the training intended to respond to
any external stimulation by applying the disturbance torque
to the device.

          Specifically, the user steps onto the device with
his/her feet in contact with the plate 1 and attempts to
15   make a balance as much as possible so as not to lean
laterally with respect to the body of the user. The
rotation angle of the plate 1 in the lateral direction with
respect to the user's body is measured by the angle sensor
3 while the rotation torque of the plate 1 is measured by
20   the rotation torque measuring mechanism, and the measured
values are supplied to the kinetic model analyzer as shown
in Fig. 3. To determine the rotation torque, the forces
applied by the left and the right feet onto the plate 1 are
measured by the pair of force plates 41 respectively and
25   the rotation torque is calculated with the arithmetic
processing unit by applying the measured force values to
the equation (2) as shown below, which is associate with
Fig. 4 for easy understanding, and thus calculated rotation

torque value is supplied to the kinetic model analyzer as shown in Fig. 3. Alternatively, the rotation torque may be measured by the rotation torque sensor 42 and the measured value may be supplied to the kinetic model analyzer.

5   In use of the pair of force plates, the rotation torque, T_m, is calculated in the following equation:

$$T_m = L(F_r - F_l)\cos\theta \quad \cdots \cdots \cdots \cdots \cdots (2)$$

where: T_r: Force applied to the plate by the right foot (N);

10   T_l: Force applied to the plate by the left foot (N); and

          L: Distance from the revolving shaft to the force plate (m).

The kinetic model analyzer, by using the equations 15 (1) and (2), calculates an angle of equilibrium (an angle making the force applied by the user in balance with the rotating force of the motor) of the plate 1, which may vary in dependence on the forces applied to the plate 1, to provide the appropriate control so that the motor 2 is 20 rotated to swing the plate 1 and thus to provide the balance training for the user. That is, the angle of equilibrium may be modified by increasing or decreasing the rotating force of the motor, and the user tries making a balance to achieve thus modified angle of equilibrium, 25 thereby effecting the balance training to be provided.

It is to be noted that in the above equations (1) and (2), the values of the viscous braking coefficient and the spring constant are those having been virtually introduced

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in the calculator (kinetic model analyzer) when determining the angle of equilibrium, and those values are known when the control is provided. It is further appreciated that the disturbance torque value represents the amount to be

5   given by the controller when the angle of equilibrium is determined, and it is a known value. Therefore, the measurement of the rotation angle and the rotation torque can provide the calculated value for the angle of equilibrium, as discussed above.

10   Further, the training can be performed independently and exclusively on each one of three organs, including the semicircular canal, the vision and the deep sensibility, each governing a personal capability of balancing, by blocking the visual information, restricting the rotation

15   of the head segment or locking the leg segment (ankle, knee joint) in the immobilized state during the training.

Fig. 5 shows graphical representations of the simulation results illustrating how the rotation torque and the rotation angle vary over time in conjunction with the

20   change in viscous braking coefficient for the high or low level of performance in respective personal capability of balancing. Both of D015E80 and D015E95 represent the cases with the relatively small viscous braking coefficient, one plotting the variation for the relatively low level of

25   performance in the personal capability of balancing, the other plotting the variation for the relatively high level of performance in the personal capability of balancing, while both of D100E80 and D100E95 represent the cases with

the relatively great viscous braking coefficient, one

plotting the variation for the relatively low level of

performance in the personal capability of balancing, the

other plotting the variation for the relatively high level

5   of performance in the personal capability of balancing. It

is to be noted that each of D015E80, D015E95, D100E80 and

D100E95 simply designates the reference numeral for the

data illustration.

It can be seen from Fig. 5 that the variation in the

10   rotation angle is greater with the smaller viscous braking

coefficient, while the variation in the rotation angle is

smaller with the greater viscous braking coefficient. It

is further seen that the higher level of performance in the

personal capability of balancing can adjust the rotation

15   angle with a smaller rotation torque.

The balance training specified in the semicircular

canal is feasible by blocking the visual information and

restricting the motions in the leg and body trunk segments

during training.

20   The balance training specified in the vision is

feasible by restricting the motions in the head, body trunk

and leg segments and providing a video image of the

external world in synchronism with the rotation angle of

the plate during the training.

25   The balance training specified in the deep

sensibility using muscle in the body trunk segment is

feasible by blocking the visual information, restricting

the head segment and restricting the motion in the leg

segment during the training.

The balance training specified in the deep
sensibility using joint and muscle in the leg segment is
feasible by blocking the visual information, restricting

5   the head segment and restricting the motion in the body
trunk segment during the training.

The blocking of the visual information may be
achieved by covering eyes with a blinder, for example.

The restricting of the head/body trunk segment may be

10   achieved by placing the armpits on the bars, such as hand-
rails, with the body leaning against the bars.

The fixedly locking of the leg segment may be
achieved with a certain type of assist tool inhibiting the
bending motion in the ankle and/or the knee joint, which is

15   mounted in the leg segment so as to prevent the movement
and/or rotation thereof relative to the plate 1. It may be
also feasible by the user taking the sitting posture.

Although the present invention has been described in
the illustrated embodiments, the present invention is not

20   limited to those embodiments but many variations thereof
will be apparent to those skilled in the art without
departing from the technical scope defined in the appended
claims.

25   INDUSTRIAL APPLICABILITY

The balance training device according to the present
invention, owing to its configuration as described above,
can achieve the rotation of the plate with a user carried

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thereon in the lateral direction with respect to the body of the user while eliminating the need for any complicated linkage mechanism. Further, the balance training device of the present invention is suitably applicable as a training device allowing for the training independently and exclusively directed to each one of the three organs, including the semicircular canal, the vision and the deep sensibility, each governing a personal capability of balancing.

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